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Toxoptera citricida (Kirkaldy) (Hemiptera, Aphididae) and its natural enemies in Spain

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Abstract: The aphid *Toxoptera citricida* (Kirkaldy) is the most efficient vector of *Citrus tristeza virus* (CTV) in the world, and it can transmit the more aggressive isolates of CTV. *T. citricida* is present in most of the zones growing citrus in the world, but it was absent from the Mediterranean Basin and North America until middle 1990's. Nevertheless, it was detected on citrus trees in 1994 in Madeira, in 1995 in Florida, in 2002 in Asturias, Spain (in yellow water traps), in 2003 in northern mainland Portugal, and in 2004 in southern Galicia, Spain, even though the three last detections were not published till 2005. As a consequence of its detection in Spain, several surveys and studies were undertaken from 2005. The main results are listed below.

Currently, *T. citricida* is present on citrus along the Atlantic coast in the northwest quadrant of the Iberian Peninsula. In Asturias, it presents a minimum in winter and other one in summer, but the last one is shorter than the minimum which Mediterranean citrus aphids have too. *Chaenomeles speciosa* (Rosaceae) has been found as an occasional alternative host for *T. citricida*. No winter eggs of *T. citricida* have been seen. CTV spread has not been detected in northern Spain. *T. citricida* is attacked in the Atlantic area by several natural enemy species, most of them present in the Mediterranean zone.

Key words: *Toxoptera citricida*, citrus, parasitoids, predators, *Citrus tristeza virus*

Introduction

Citrus tristeza virus (CTV) causes the most harmful and destructive disease affecting citrus (Bar-Joseph *et al*., 1989). In fact, the losses it causes are estimated at about 38 million trees in America, more than 55 million in the Mediterranean basin, especially in Spain, and about 5 million in other areas. Furthermore, to this we must add the low fruit quality and production loss of several million trees, grafted onto tristeza-tolerant stocks but that have been infected with severe CTV isolates, causing stem pitting in the rootstock and/or the variety (Bar-Joseph *et al*., 1989; Rocha-Peña *et al*., 1995; Cambra *et al*., 2000a).

CTV is transmitted by several aphid species (Hemiptera, Aphididae) in a semipersistent way. The most effective vector of CTV in the world is *Toxoptera citricida* (or *citricidus*) (Kirkaldy) (Meneghini, 1946; Bennet and Costa, 1949; Costa and Grant, 1951). However, *Aphis gossypii* Glover is the main vector in Spain, Israel, some citrus-growing areas of California (USA) and all those places where *T. citricida* is absent (Dickson *et al*., 1951; Bar-Joseph and Loebenstein, 1972; Raccah *et al*., 1976; Hermoso de Mendoza *et al*., 1984; Yokomi *et al*., 1989; Gottwald *et al*., 1996, 1997; Cambra *et al*., 2000a). In addition, other aphid species have been described, which are less effective CTV vectors: *A. spiraecola* Patch (Norman and Grant, 1954; Hermoso de Mendoza *et al*., 1984), *T. aurantii* (Boyer de

Fonscolombe) (Norman and Grant, 1956; Hermoso de Mendoza *et al*., 1984), *Myzus persicae* (Sulzer) (Varma *et al*., 1960), *A. craccivora* Koch and *Uroleucon jaceae* (Linnaeus) (Varma *et al*., 1965). On the other hand, *T. citricida* transmitted CTV 6-25 times more effectively than *A. gossypii* in parallel assays with the same virus isolates (Yokomi *et al*. 1994).

T. citricida is probably native to China, from where it must have spread to other countries in the East and South of Asia, Australia and sub-Saharian Africa. It seems quite probable that *T. citricida* went from South Africa to Brazil and Argentina with plant material, thus introducing tristeza into these countries (Moreno, 1995). After the epidemics in 1930-40 in Brazil and Argentina (in which 30 million citrus trees died), *T. citricida* advanced slowly toward the North of America until reaching Venezuela in 1976, where it caused the death of 6 million citrus trees over ten years (Rocha-Peña *et al*., 1995). In 1989, *T. citricida* was detected in Costa Rica (Lastra *et al*., 1991) and later in Belize (Pollard, 1997), in Guatemala (Palmieri, personal communication) and in Yucatan (Michaud and Álvarez, 2000), having also occupied the Caribbean islands, and in 1995 it arrived in the United States, to Florida to be precise (Moreno, 1995).

Concerning the Mediterranean basin, although citrus fruits had been cultivated for many centuries, the introduction of tristeza did not take place until the decade of 1920, and did so without the presence of *T. citricida*. Consequently, the tristeza problem here was relatively small and essentially centred in Spain and Israel. However, in 1994 *T. citricida* was detected on the island of Madeira, at the gateway to the Mediterranean (Fernandes and Cruz de Boelpaepe, 1994). Repeated surveys were made in continental Portugal without finding the aphid (Cruz de Boelpaepe and Ferreira, 1998) until 2003, when it was detected for the first time in the North of Portugal. In 2005 it was discovered that *T. citricida* had also been found in the North of Spain (in Asturias from 2002 and Galicia in 2004) (Ilharco *et al*., 2005) and this fact meant that *T. citricida* had been introduced into the Mediterranean basin. This posed a serious threat to the citrus industries in the area, both in terms of the pest itself and in its role as main vector of the tristeza, especially because the current strategy uses rootstocks that are tolerant to less aggressive strains of CTV, but cannot withstand such severe isolates of the virus.

The main Spanish citrus-producing regions are located in the East and South of the Iberian Peninsula, that is to say, quite far from the north-western areas where *T. citricida* had been detected. However, the danger of the aphid's propagation was evident, and therefore different plans of action were undertaken in Spain. On one hand, two projects were developed: "Preventive biological control to face the introduction of *Toxoptera citricida*" (INIA, 2005-08) and "Survey and studies of *Toxoptera citricida* on the Cantabrian cost" (IVIA, 2006-07).

Several surveys and different action-plans of another type (meetings, visits, etc.) were also carried out in the North of Spain from 2005. The aims of all these actions were, firstly, to study the situation of *T. citricida* in the North of Spain (geographical distribution, biological cycle and population dynamics, composition and dynamics of the fauna of natural enemies, search for alternative hosts to citrus, and survey of *Citrus tristeza virus*) and, secondly, to carry out comparative studies with other citrus aphids (population dynamics, and composition and dynamics of their natural enemies) in Valencia, the main Spanish citrus-growing area (located in the East of the Iberian Peninsula), where *T. citricida* has not appeared so far.

Material and methods

T. citricida has been surveyed using two different methods in the North of Spain. In the first place, square-based (60 x 60 cm) yellow water traps (Moericke, 1951) have been used, with

captures being collected periodically to obtain data for the aphid flight graphs. One of these traps has been placed in each of the following locations: Asturias (Villaviciosa, 2002-07; Arbón, 2002; Tapia de Casariego, 2002; Pruvia, 2002; Niembro, 2002; Argüelles, 2002-03), Cantabria (Laredo, 2006-07; Novales, 2007) and Bizkaia (Bakio, 2006; Derio, 2007). In the second place, citrus were sampled to detect the presence of *T. citricida* in 2005 (Zaragoza, Gipuzkoa, Bizkaia, Cantabria and Asturias) and in 2006 (Pontevedra, A Coruña, Lugo and Asturias). Furthermore, intensive surveys of citrus have been carried out during 2006-07 in Asturias to determine the aphid's diffusion, and eight lemon-tree plots have also been sampled periodically in order to study the pest's development over time and that of its natural enemies. Meanwhile, samples of citrus have been taken throughout the North of Spain during 2005-07 to detect *Citrus tristeza virus* using the Tissue print-ELISA test (Cambra *et al*., 2000b).

During 2006-07, the citrus network *Plan de Vigilancia Fitosanitaria Citrícola* (Generalitat Valenciana, coordinated by F. García Marí and J.M. Llorens) has periodically provided samples of citrus aphid enemies for identification, collected throughout the Valencian territory. In addition, the development of the aphid colonies and their natural enemies on clementine trees has been followed up in two plots (L'Alcúdia in 2006 and Bétera in 2007).

Results and discussion

Figure 1 shows the results of the citrus aphids survey carried out in the North of Spain in 2005: *T. citricida* was detected on citrus in Asturias (where it had previously been found only in traps) and in Cantabria (where there were no references of its presence); however, it was not observed in any of the regions surveyed further East. Figure 2 shows a small change in the eastern boundary of *T. citricida* during 2006-07, since it was also detected in Bizkaia, although only one winged specimen was captured in a trap in 2006, while in 2007 none was trapped; furthermore, no live colonies of *T. citricida* have ever been seen in Bizkaia. Figure 2 gives the current distribution of *T. citricida* in Europe: it is present on citrus all along the north-western Atlantic coast of the Iberian Peninsula, from northern Portugal to Bizkaia, Spain [data of Portugal from 2006 (European Commission, 2006)].

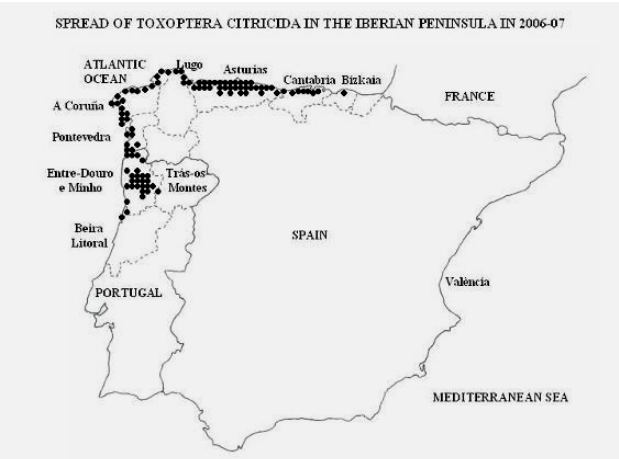

Figure 1

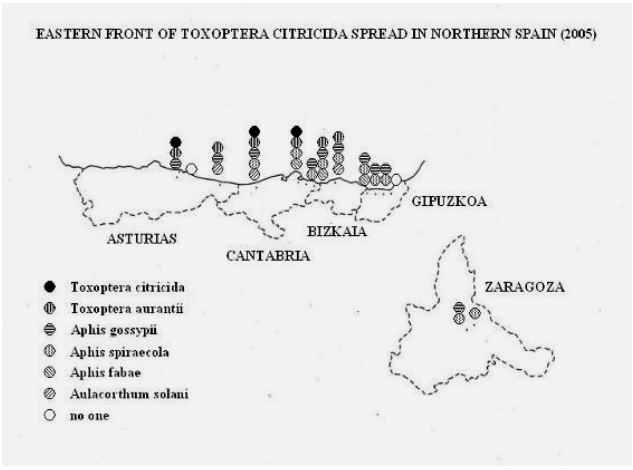

Figure 2

Figure 3 displays the time course of the winged *T. citricida* observed in Asturias, on the Atlantic, in the location where the trap has remained since 2002: In general there are two annual minimums (a very long one in winter and another very short one in summer) and two or three maximums (one or two in spring-summer and another in autumn). Figure 4 shows citrus aphid development during 2006-07 in the Valencian plots, on the Mediterranean: the two main species, *Aphis gossypii* and *Aphis spiraecola*, also usually display two annual minimums, in winter and summer (although the latter is longer than the Atlantic summer minimum), and two or three maximums (one or two in spring and another in autumn), which is common behaviour according to previous surveys (Hermoso de Mendoza *et al*., 1997).

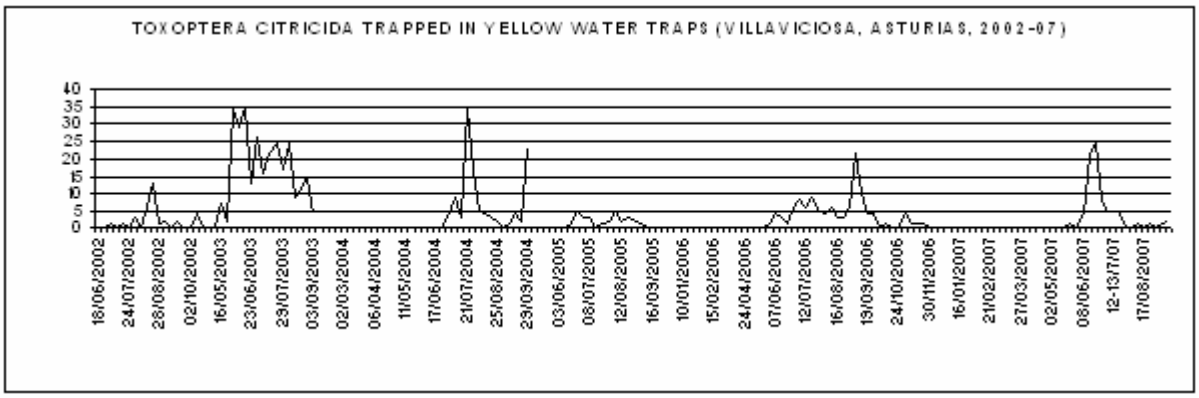

Figure 3

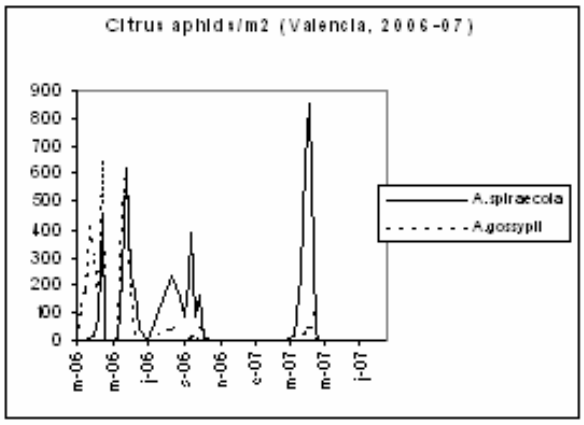

Figure 4

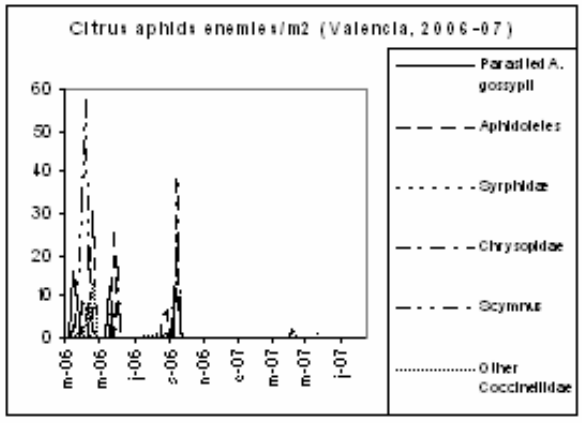

Figure 5

The natural enemies observed attacking *T. citricida* in Asturias during 2006-07 figure in Table 1. The enemies found in this period of time on the citrus aphids prospected in Valencia are also indicated there (both in the sampling plots and in the citrus network *Plan de Vigilancia Fitosanitaria Citrícola*), as well as the enemies observed in Valencia, not in these assays but in previous works (Quilis, 1930; Chalver, 1973; Michelena and González, 1987; Michelena and Oltra, 1987; González and Michelena, 1987, 1989; Llorens, 1990; Michelena *et al*., 1994; Michelena and Sanchis, 1997; Rojo, 1995; Urbaneja *et al*., 2005; Alvis Dávila and Garcia Marí, 2006). Looking at this Table, we can verify that *T. citricida* is attacked on the Spanish Atlantic coast by a large number of parasitoids and predators, most of which are also present on the Mediterranean coast.

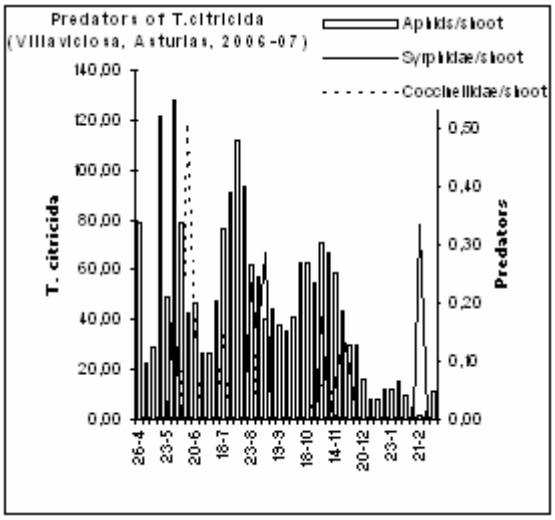

Figure 6

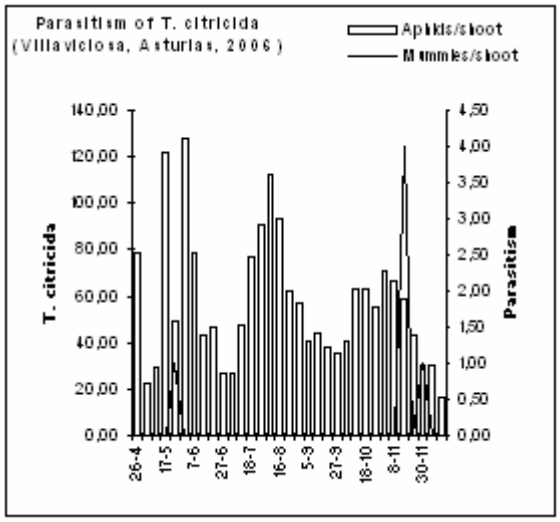

Figure 7

Table 1. Citrus-aphid enemies found in Spain on *T. citricida* (in Asturias) and on other citrus aphids (in Valencia) in 2006-07.

CITRUS APHIDS ENEMIES (2006-07)	on T. CITRICIDA (ASTURIAS)	on OTHER CITRUS APHIDS (VALENCIA)		
		Plots	Citrus network	Previous
ACARI				
Allotrombium pulvinum	X		X	
HYMENOPTERA APHIDIINAE				
Lysiphlebus fabarum	X			X
Lysiphlebus testaceipes	X		X	X
Trioxys angelicae	X			X
Trioxys acalephae			X	X
DIPTERA CECIDOMYIIDAE				
Aphidoletes aphidimyza	X	X	X	X
DIPTERA SYRPHIDAE				
Episyrphus balteatus	X			X
Syrphus ribesii	X			
Syrphus vitripennis	X			X
Epistrophe eligans	X			X
Meliscaeva auricollis	X			X
Eupeodes corollae		X		X
DIPTERA CHAMAEMYIIDAE				
Leucopis sp.	X			X
NEUROPTERA CHRYSOPIDAE				
Chrysoperla carnea	X	X	X	X
Chrysopa septempunctata	X			X
HEMIPTERA ANTHOCORIDAE				
Orius majusculus	X			
COLEOPTERA COCCINELLIDAE				
Adalia bipunctata	X			X
Coccinella septempunctata	X		X	X
Propylea quatuordecimpunctata	X	X	X	X
Scymnus subvillosus		X	X	X
Scymnus interruptus		X		X

Figures 6 and 7 show the time course of the main natural enemies (predators and parasitoids, respectively) of *T. citricida* in Asturias during 2006-07, with Syrphidae and Coccinellidae proving to be the most abundant predators. Figure 5 shows the same for the citrus aphid enemies in Valencia, but here the most numerous enemies are Cecidomyiidae (*Aphidoletes aphidimyza*) and Coccinellidae (particularly *Scymnus* spp.). The development of all the enemies is always synchronized, as is logical, with that of the aphids.

From the observations as to how *T. citricida* survives the winter in the North of Spain, it has been proven that it does so as nymphs or adults on shoots or buds of citrus in protected places. Neither eggs nor sexual forms have been found.

Once in Asturias, *T. citricida* was detected forming colonies on a different plant to citrus, the bush *Chaenomeles speciosa* (Rosaceae), never referred to previously as a host of this aphid.

Surveys of *Citrus tristeza virus* carried out on citrus in the North of Spain in 2005-07, have recorded only 3 CTV positive trees out of 1123 analyzed, that is to say, 0.26%. This represents a low incidence of the virus, which has not spread for the moment.

Conclusions

- *T. citricida* is present on citrus all along the NW Atlantic coast of the Iberian Peninsula, from northern Portugal to Bizkaia, Spain.
- In Spain, minimums are recorded for *T. citricida* on the Atlantic coast and citrus aphids on the Mediterranean coast both in winter and in summer, but the latter is shorter on the Atlantic.
- *T. citricida* is attacked on the Atlantic by several natural enemy species, most of which are present on the Mediterranean as well.
- One occasional alternative host plant species has been found for *T. citricida*: *Chaenomeles speciosa* (1st reference in the world).
- No sexual forms of *T. citricida* have been found.
- CTV spread has not been detected in northern Spain.

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